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CONTAMINATION CONTROL REQUIREMENTS DOCUMENT JSC 30426 RECOMMENDED UPDATES

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Abstract. Contamination control requirements for the Space Station have been evolving over the last few years. Workshops, comments by experimenters and continuing analysis have resulted in recommending changes to the November 19, 1986 version of Space Station External Contamination Control Requirements, JSC 30426. These are summarized and presented herein, so that the requirements can be revised as soon as possible, to minimize costly design impacts on the Space Station.

1.0 INTRODUCTION

The changes recommended to JSC 30426, presented here, are a result of the Jan 28-30, 1987 "Space Station Payload Contamination Compatibility Workshop" held in Denver and subsequent workshops and analyses. The majority of these recommended changes were proposed by payload personnel and the others by members of the contamination control community.

2.0 WORKSHOP RECOMMENDATIONS

The Workshop held in Denver, Jan 28-30, 1987 addressed the current (Nov 19, 1986) Space Station Contamination Control Requirements and changes recommended by the payload/ contamination community. Table I lists the Jan 1987 workshop participants.

TABLE I. LIST OF WORKSHOP PARTICIPANTS.

Jack Barengoltz	-	JPL
James Carney	-	MATSCO/JSC
Nancy Carosso	-	GSFC
Steve Chinn	-	SEA
James Cramer	-	SEA
Alice Dorries	-	MSFC
Gabriel Epstein	-	GSFC
Ray Gause	-	MSFC
Tim Gordon	-	SEA
Patricia Hanson	-	JPL
John Hughes-Blanks	-	SEA
Don Jennings	-	GSFC
Charlie Jones	-	MSFC
Lubert Leger	-	JSC
Carl Maag	-	JPL
Dave McKay	-	JSC

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TABLE I. LIST OF WORKSHOP PARTICIPANTS - Cont.

Gerry Murphy	-	University of Iowa, Iowa City, IO
Gary Musgrave	-	MATSCO/HQS
Sherman Poultney	-	Perkin-Elmer
Ray Rantanen	-	SEA
Reese Reumont	-	JSC
Jeffrey Scargle	-	ARC
Russ Seebaugh	-	SEA
Mark Sistilli	-	SAIC/Washington, DC
Gerald Sharp	-	Univ. Research Foundation, Greenbelt, Maryland
Srini Srinivasan	-	MATSCO/JSC
Doug Torr	-	Univ. of Alabama, Huntsville, Alabama
Marsha Torr	-	MSFC
June Tveekrem	-	GSFC
Fred Witteborn	-	ARC

2.1 RECOMMENDED CHANGES TO JSC-30426

The workshop participants recommended the following changes to the Nov. 19, 1986 version of the JSC-34026 document. These changes pertain to Section 4.0 of that document.

a. Paragraph 4.5.1.1

Insert word "Continuum" before each "background" in the paragraph. Add sentence "Line and band emitting species will have column densities satisfying 4.5.1.2.1.", at the end of the paragraph.

b. Paragraph 4.5.1.1

The requirement stated here should include contributions from particles <5 microns.

c. Paragraph 4.5.1.2.2

The allowable limits in this paragraph should be adjusted to be compatible with Table 4-1, which is the criteria payload personnel will accept.

Old: 1×10^{13} molecules/cm^2 each for O_2, N_2, H_2 noble gases, and for all other UV and non-IR active molecules combined (total not to exceed 5×10^{13} molecule/cm^2)."

Replace 1×10^{13} and 5×10^{13} to read:

New: 2×10^{11}molecules/cm^2 each for O_2, N_2, H_2, for noble gases, and for all other UV and non-IR active molecules combined (total not to exceed 1×10^{12} molecules/cm^2)

d. <u>Paragraph 4.5.1.3.1</u>

Old: Control of particles less than 5 microns in size shall meet TBD requirements

New: Control of particles less than 5 microns in diameter shall not contibute more noise than the zodiacal background, time-averaged over an orbit.

e. <u>Paragraph 4.5.1.3.2</u>

Old: TBD

New: 4.5.1.3.2A - The particle deposition on surfaces with an acceptance angle of 2π sr shall not exceed 0.5 percent obscuration. 4.5.1.3.2B - The change in BDRF due to particle deposition on surfaces with an acceptance angle of 0.1 sr shall not exceed 50 percent (clean versus contaminated).

f. <u>Paragraph 4.5.2.2</u>

Requirements in 4.5.1.3.2 shall apply during both quiescent and non-quiescent periods.

g. <u>Table 4-2</u>

Add "continuum" after "infrared" in the title, and change wavelength ranges as follows:

Old: (micrometers)

1
5
10
≤ 30
>30
300

New: (micrometers)

1 - 3
3 - 7
7 - 15
15 - 30
30 - 200
200 - 500

It is further recommended the final level of 1×10^{12} molecules/cm^2 be verified or updated by Dr. Doug Torr and presented at the next CCWG.

<u>NOTE</u>: The changes to C in paragraph 4.5.1.2.2 above were based on preliminary estimates by Dr. D. Torr. Subsequent to this workshop, Dr. Torr has developed better estimates of molecular densities that meet or exceed zodiacal brightness levels. These new estimates should be collected, reviewed, and used in place of the above recommendations.

3.0 ADDITIONAL RECOMMENDATIONS

These recommendations are a result of workshops and analysis during 1987.

3.1 MOLECULAR COLUMN DENSITIES

The allowable molecular column densities in paragraph 4.5.1.2 of JSC 30426 do not correspond to the zodiacal light levels that are stated in paragraph 4.5.1.1 and tables 4.1 and 4.2. Reconcilliation should be accomplished by requesting Dr. D. Torr, UAH, to update these values based on the synthetic molecular spectra work he has accomplished during 1987.

3.2 EARTH POINTING BRIGHTNESS LEVELS

The location of experiment vents can be optimized to reduce the impact to experiment lines-of-sight. In order to do this, the Earth viewing systems brightness requirements is required as a function of wavelength.

Once this brightness requirement is determined, the column density of molecules that generate this level can be determined by Dr. D. Torr, UAH. It is anticipated the requirement will be similar in form to that of the stellar viewing systems represented in JSC 30426; ie, that the acceptable contaminant brightness level will be equivalent to the naturally occurring background.

The requirements may have to be subdivided into true earth viewing and earth limb viewing.

3.3 EXCITED MOLECULE DISCRIMINATION

Recent studies show that not all molecules have the same effect in adding to background brightness even if they are the same species. For example, nitrogen from a vent, emitted into free space, is in a different excited state than ambient nitrogen that impacts the vehicle surface and is re-emitted. Therefore, these two sources of nitrogen must be treated differently in their contributions to molecular column densities and resulting brightness. A meeting between Dr. D. Torr and others of the Contamination Workshop participants should be held to further explore this issue.

3.4 Surface Deposition

The deposition rates on surfaces in paragraph 4.5.1.4 of JSC 30426 appear to be overly restrictive for surfaces such as thermal control, solar arrays, radiators, habitation modules, etc.

The allowable levels indicated in JSC 30426, for a flat surface on the truss at 300°K, is $1 \times 10^{-14} g\ cm^{-2}\ s^{-1}$. This equates to a deposition thickness of 30 angstroms per year, roughly equivalent to 10 molecular layers. This level is appropriate for critical UV optics, but appears too restrictive for operational surfaces.

This single required maximum level in JSC-30426 places severe restrictions on all Space Station outgassing rates. Additionally, the Shuttle when docked appears to violate these levels in about one day.

A Contamination Control Working Group should be convened to resolve this and other issues.

3.5 PLASMA REQUIREMENTS

The requirements in JSC-30426 pertain primarily to quiescent payload viewing periods. The only non quiescent period requirement is mentioned in paragraph 4.5.2 and relates to deposition.

Because of high densities from vents or engines, ionizable species or other unique sources can cause plasma perturbations and possible arcing near the solar arrays and other requirements may need to be developed. The non quiescent periods have been assumed (to date) to be times when large quantities of vented material are allowed, as well as engine firings, resistojet operations, unlimited EVA activities, Shuttle docking, etc.

It appears that at least, a density limit on gaseous species at critical locations must be imposed to reduce the chance of detrimental perturbations or arcing.

A coordinated effort between the plasma and contamination working groups should be implemented to resolve this issue.

3.6 QUIESCENT PERIOD DURATION

A requirement in JSC 30426 states "Generally, environment conditions as stated in paragraph 4.5.1 shall be maintained for up to 14 days during required viewing periods".

This was intended to allow attached payload users to have a long period to collect data from a one time event.

It appears this may be overly restrictive on Space Station and would cause cost impacts on the Space Station design to allow storage of all wastes for a 2 week period. Additionally, the use of attitude control engines is expected to be required during nearly every orbit.

Since almost all attached payloads would take data only during a portion of an orbit, the remainder of the orbit could be used for engine firings and vents. Therefore the 14 day period should be modified to minimize Space Station design impacts.

4.0 RECOMMENDED VALUES FOR SELECT CHANGES

Based on data obtained from previous flights and laboratory testing, recommended deposition levels for surfaces such as solar arrays and thermal control are presented in this section.

4.1 SOLAR ARRAY DEPOSITION LEVELS

A spectral extinction coefficient was determined from transmissive optics flown on Gemini XII (Muscari, 1967). The exact nature of these deposits was not determined. The samples were chosen because they represent space flown optics on which a great many measurements were made. The extinction coefficient arrived at is shown in Figure 1. Data available on outgassed deposits and bipropellant engine deposits yields an extinction coefficient that correlates to the data of Figure 1, within 30 to 50%. By applying the spectral extinction coefficient to the spectral response of a solar cell for varying amounts of deposited contaminant, a percent power loss versus deposition can be plotted as shown in Figure 2 (Rantanen, 1974).

The figure shows that solar arrays with a spectral response similar to those used on Skylab will experience near 5% degradation with a deposit of 5000 Å. If the solar array lifetime is 10 years (needs to be determined) before refurbishment, then approximately 500 Å per year is allowed. This relates to approximately 40 Å/yr which is currently given in paragraph 4.5.2.1 in JSC 30426.

Actual allowed degradation and lifetime requirements must be determined before updated allowable deposition levels can be specified. If this data is not available, then a higher deposition level of 500 Å (5×10^{-6} gm cm $^{-2}$) per year is recommended.

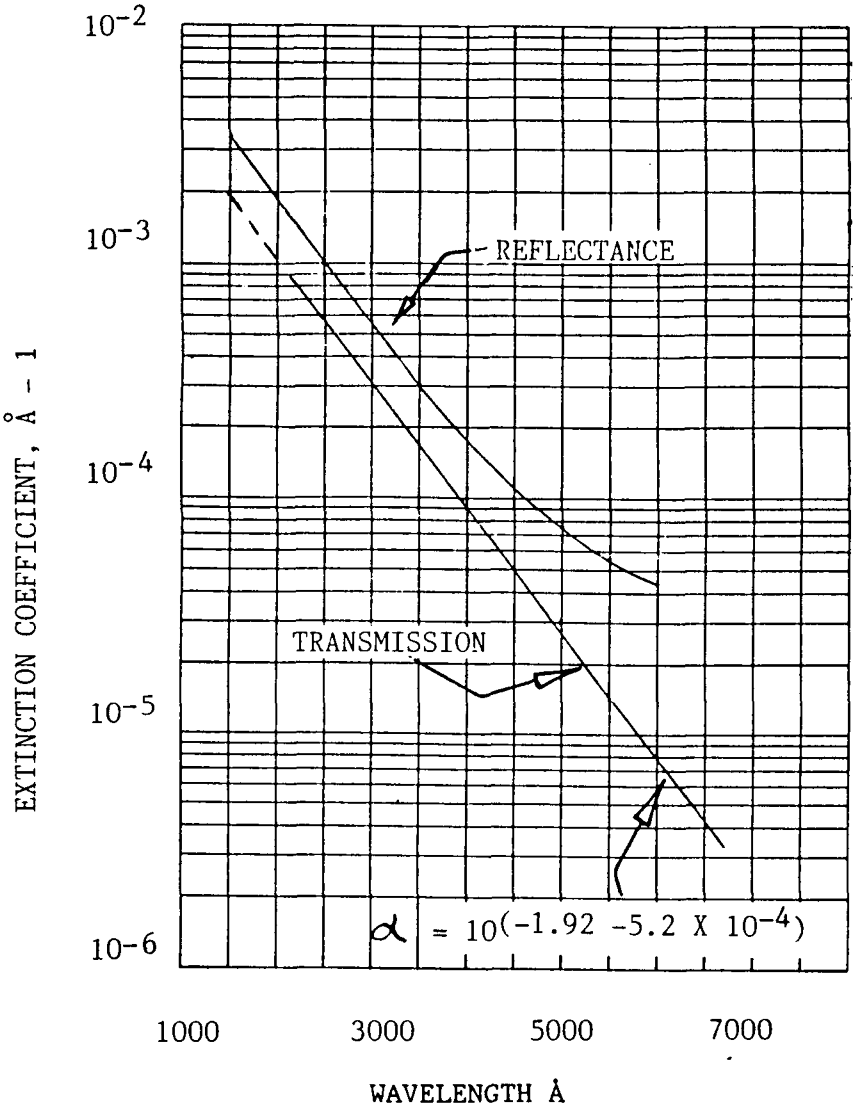

Figure 1. Transmission and reflectance extinction coefficients.

4.2 THERMAL CONTROL SURFACE DEPOSITION LEVELS

Data obtained from Skylab showed changes in solar absorptivity for two types of paint. Samples returned from Skylab were estimated to have particular levels of deposition based on real time deposition monitors on board and model predictions. The samples were exposed to significant levels of solar ultraviolet and were yellow or tan in color. Figure 3 shows the results in change in solar absorptivity versus accumulated deposition for two white paints, Z93 and S13G. The solar absorptivity change allowed will dictate the absorptivity of allowable maximum deposition.

If the allowed absorptivity change due to deposition, over the lifetime of a surface, was 0.1 then the allowable deposition is about 2 x 10^{-5} gm cm^{-2}, or a thickness of 2000 Å for a unit density deposit.

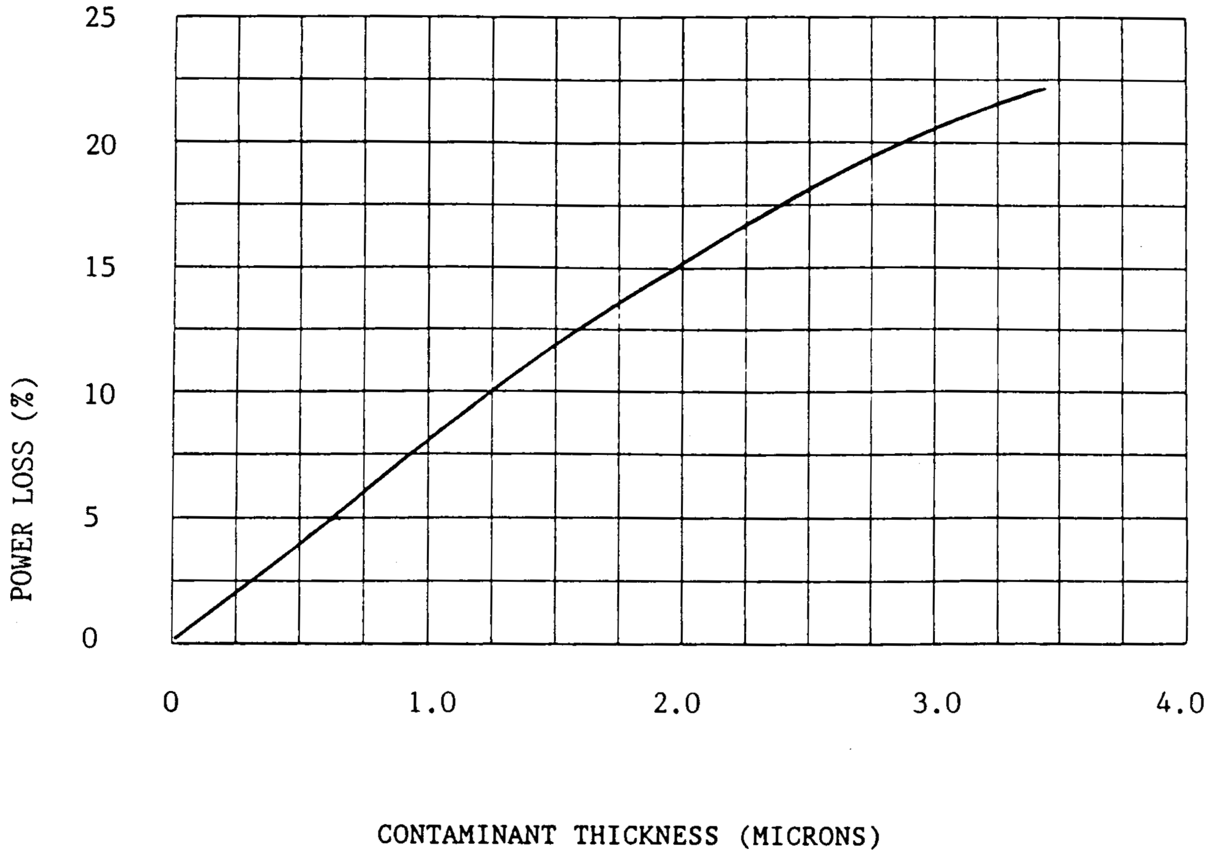

Figure 2. Solar array percent power loss versus deposition.

If these levels are for experiment surfaces on the transverse booms, the actual rate will depend on the total exposure time. For an experiment that resides for 6 months on the truss, the allowed rate would be 1.2×10^{-12} gm cm^{-2} s^{-1}. If, on the other hand, a thermal control surface was exposed for 10 years the allowable 2000 Å would be 6.3×10^{-14} gm cm^{-2} s^{-1}, and if exposed for 30 years, 2×10^{-14} gm cm^{-1} s^{-1}.

Since the truss structure, experiment surfaces, and habitation module exterior will all have different acceptable degradations and lifetime, a range of allowable deposition rates will need to be determined.

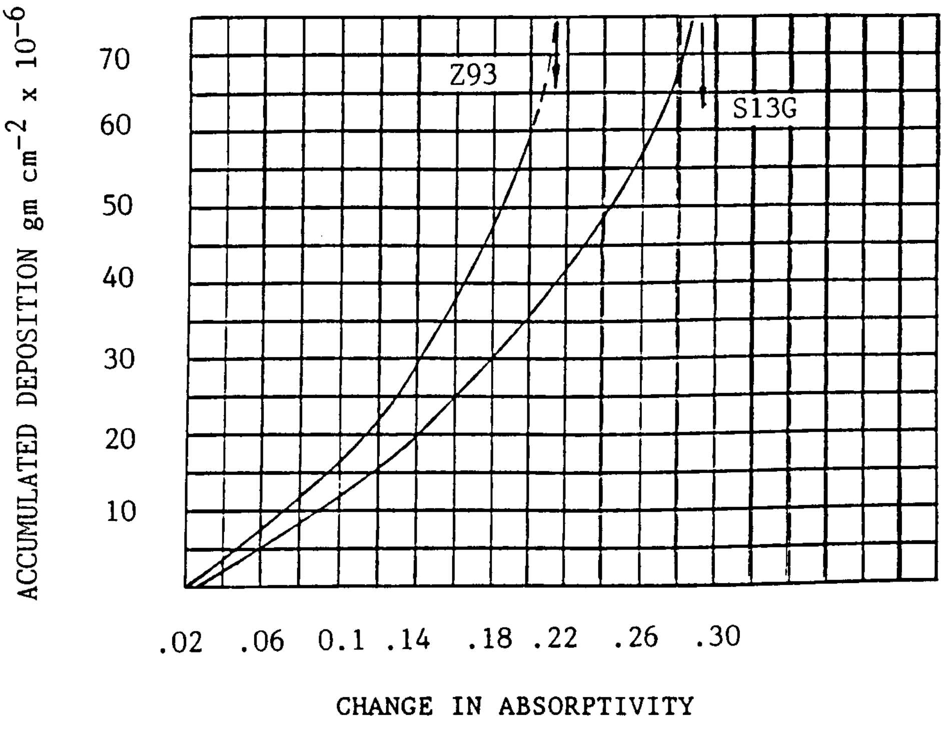

Figure 3. Change in solar absorptivity versus deposited contaminant thickness

Figure 4 shows the solar absorptivity change on S-13G white paint as a result of RCS engine tests at LeRC. Ultraviolet was present during and after deposition. The deposited material in this test should be similar to the deposits from the Shuttle engines. This data shows that the change in solar absorptivity reaches a maximum near 0.1 as compared to 0.3 for the outgassed deposits shown in Figure 3 for S13G.

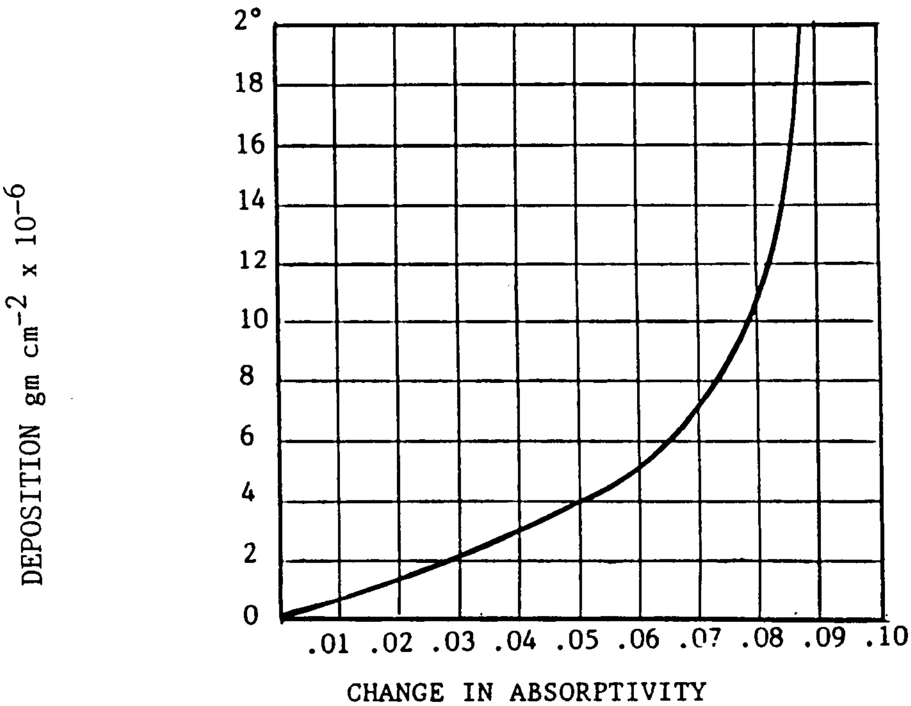

Figure 4. A $\Delta\alpha_S$ change for bipropellant engine exhausts.

5.0 GAS DENSITY NEAR SOLAR ARRAYS

The density of gases near the solar arrays is of interest because of the relatively high voltage (160V) and potential for arcing.

From previous modeling efforts and flowfield analysis of vents and engines, a compilation of gas densities from various sources has been completed.

Table II shows the gas density and the major species involved. Hopefully, this data will aid in determining if there is a potential problem or not.

The density for the vent is calculated on the plume centerline, for a flow rate of 0.1 gm s^{-1} for a 20 meter separation between the vent and the arrays.

The RCS engine calculations are based on a 15 meter separation for both on the plume centerline and at right angles to it.

Table II . Gas densities near solar arrays

SOURCE	MOLECULES/cm^3	SPECIES
RAM PRESSURE	1.2×10^{10}	N_2, O, NO
LEAKAGE	6×10^8	H_2, O_2, H_2O
OUTGASSING	8×10^7	LARGE ORGANIC MOLECULES
VENT	2×10^9	H_2, O, N_2, O_2
RCS (ON AXIS)	6.8×10^{12}	H_2O
RCS (NORMAL TO AXIS)	4.5×10^9	H_2O

For normal operating periods, the major contributor is the ambient ram pressure. The RCS engines provide the highest densities, depending on their firing direction relative to the solar panels.

6.0 CONCLUSIONS

The recommended changes presented in this paper should aid both the attached payloads and the Space Station designers. Early implementation of these changes will reduce cost impacts at a later date.

As the Space Station design evolves the contamination control requirements will require revisiting and updating. Changes in altitude and configuration will have the largest impact on contamination if the contamination sources remain comparable.

Continuous analysis and monitoring of the Space Station configuration, operations and potential contamination sources is required to assure an optimum environment for experimentation and research.

A monitoring package is essential to verify compliance, update models, determine experiment environments to assist in data reduction and detect anomalies that occur and would otherwise be unknown. Ideally these monitoring packages would be directional in nature and would measure surface molecular deposition, identify gas species, measure velocity of gas species, determine surface degradation and detect particulates in space as well as on surfaces.

REFERENCES

Muscari, J.A. and Cunningham, A.C., Gemini XII Contamination Study, Martin Marietta Report R-67-2, 1987.

Rantanen, R.O. and Thornton, J.R., Deposited Contaminants Effect on Solar Array Power Loss, Conference Record of the 10th IEEE Photovoltaics Specialist Conference, 1974, Palo Alto, California, November 13-15, 1973.